Hyperon Electroproduction with CLAS

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We present data for the electroproduction of K^+ Λ and K^+ Σ states at beam energies of 2.4 and 4.0 GeV. The data were taken with the CLAS spectrometer, a large-acceptance detector housed in Hall B at CEBAF. We show plots of particle mass calculated from momentum and time-of-flight as well as missing mass plots of the recoiling hyperons. We conclude by plotting event yields that demonstrate the large acceptance of the CLAS spectrometer, and briefly discuss prospects for further analysis.

1. Physics Motivation

The goal of the hyperon electroproduction experiments at CLAS is to measure the four structure functions, σ_T, σ_L, σ_{TT}, and σ_{LT}, which describe the reaction over a range of Q^2 from 0.5 to 3 GeV^2/c^2 and W from threshold (1.62 GeV) to 2.5 GeV. The small amount of data which exists for these reactions was taken at Cornell and at DESY [1], [2], [3] in the 1970's. These two-spectrometer experiments were only able to measure well the unpolarized structure function, σ_T . The large acceptance of the CLAS detector will allow detection of the K^+ over practically the full range of center-of-mass angles, enabling the separate determination of the physically interesting structure functions, so important for constraining theoretical models.

Kaon electroproduction data is complementary to pion data because s quarks are not present as valence quarks within the nucleon, and thus certain quark diagrams are suppressed. For this reason, the amplitudes depend on the wavefunction of the $s\bar{s}$ pair produced from the vacuum. Because the Λ is self-analyzing we will be able to measure its polarization and thus the spin of the s quark which is also sensitive to the $s\bar{s}$ quantum state. Most models assume that it is in a $^3P_0$ [4] state.

An experimental advantage of comparing Λ K^+ and Σ K^+ final states is that they act as an isospin filter. Only N^* resonances can contribute to s-channel production of the $I = 1/2$ Λ K^+ final state but both N^*'s and Δ^*'s can contribute to Σ K^+ .

We will measure the production ratio of the various hyperons, Λ, Σ, $\Lambda(1405)$, $\Sigma(1385)$, and $\Lambda(1520)$ as a function of Q^2 . If these are simple quark states differing only by spin and their production amplitudes. Previous data already indicate that the electroproduction ratio of Σ to Λ differs markedly from the photoproduction value, and also shows a large Q^2 dependence. This data was only taken for small values of t, while the CLAS will cover a wide range of t for each Q^2 and W point. Finally, we will search for missing N^* resonances which decay to K^+ hyperon final states. Many of these states are predicted to have a sizeable branching fraction [5] to hyperons.

2. Experiment Description

The data presented here comes from two beam energies, 2.4 and 4 GeV. It consists of 55 million triggers (and some 45,000 K^+ Λ and K^+ Σ events) for the 2.4 GeV sample and of 60 million triggers (and 17,000 such events) for the 4 GeV sample. A factor of six more data were taken in early 1999 and are presently being analyzed.

The CLAS spectrometer is built around a six-coil superconducting toroidal magnet which provides a strong azimuthal magnetic field. Each of the six inter-coil volumes (called a 'sector') is instrumented with tracking chambers. Because the predominantly azimuthal field direction insures that scattered tracks which originate from the target remain within a single sector, the CLAS can be thought of as six independent spectrometers, a circumstance which allows rigorous checks of possible systematic uncertainties.

Outside the combined magnet and tracking chambers lies the outer detector which consists of Cerenkov detectors (CC), time-of-flight counters (TOF), and electromagnetic calorimeters (EC). The TOF counters are used for triggering the data acquisition system as well as for charged particle identification by measuring the track's velocity. Timing resolution between 80 ps (small angle) and 140 ps (large angle) enable us to identify charged kaons, and reject charged pions at the two sigma level up to 2 GeV/c momentum.

3. Event Analysis

We selected events by first requiring an electron candidate, defined as a drift chamber track matched to a hit in each of the outer detectors, CC, TOF, and EC. The energy as measured in the EC was required be consistent with the measured track momentum.

For those events with a good electron candidate we searched for positive tracks which matched to a hit in the TOF counters. By subtracting the event start time, calculated from the electron TOF signal and its flight path, from the TOF signal for the charged track, we calculated its time-of-flight, and thus its mass. In Fig. 1a we show a histogram of the calculated particle mass for a sample of positively charged particles. Between the large peaks at the π^+ and proton mass, a small peak at the K^+ mass is evident.

After applying a cut of 0.4 to 0.6 to the mass spectrum, we calculate the missing mass of the hyperon recoiling against the scattered electron and the kaon. This spectrum is shown in Fig. 1b. We approximated the shape of the underlying background by assuming that it is dominated by cases in which a pion is misidentified in the TOF system as a kaon. We took pion candidates (mass less than 0.4 in Fig. 1a), assigned them the mass of the kaon, and calculated the apparent mass of the recoil hyperon. This spectral shape was normalized to the portion of the hyperon spectrum below the Λ peak. The normalized

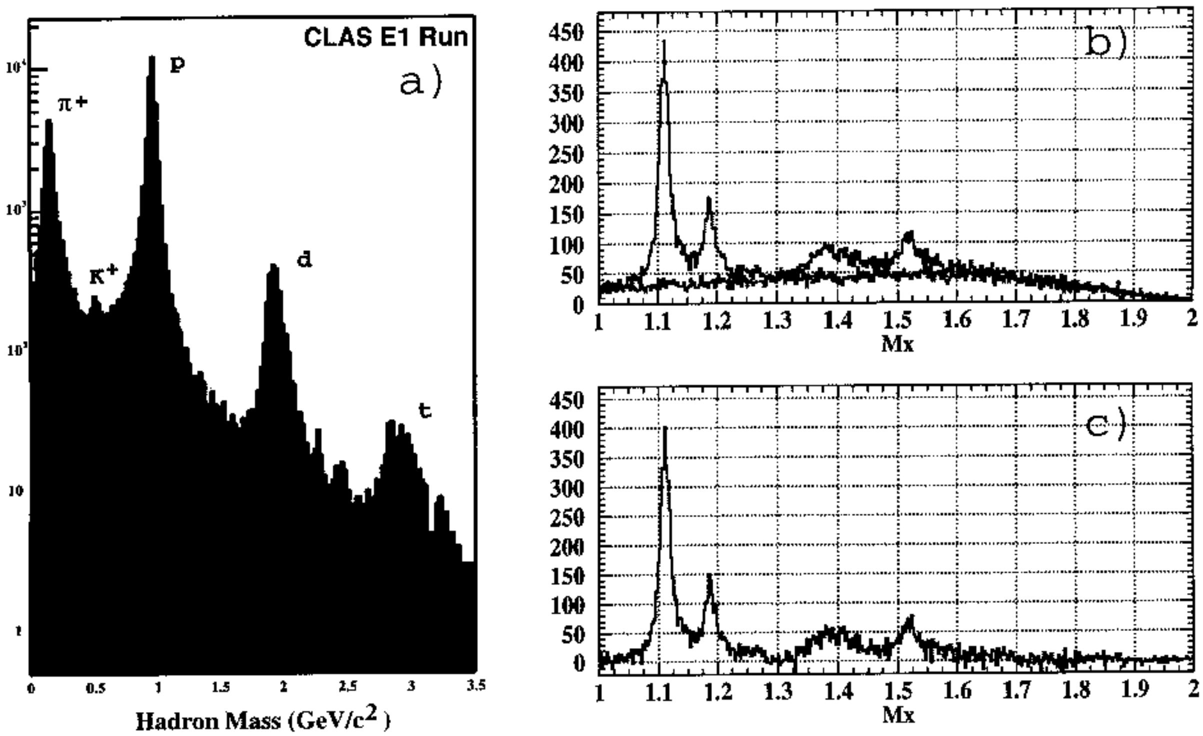

Figure 1. a) Histogram of the mass of positively charged tracks calculated from the measured track's velocity and momentum. b) Histogram of the missing mass recoiling from the scattered electron and K^+ ; overplotted is a background spectrum as described in the text. c) Background-subtracted missing mass histogram.

4. Corrections to Yields

The background-subtracted yields have been corrected for geometrical acceptance, decays in flight, beam-target luminosity, finite bin-size and radiative effects. We are still in the process of checking the corrections and do not yet have cross-sections to report. However, we show in Fig. 2 the distribution of our events in Q^2 and W and in kaon center-of-mass angles Φ^* and $\cos\theta^*$ to demonstrate the large acceptance of the CLAS detector. In Fig. 2a we show the yield for events with a detected K^+ plotted versus Q^2 and W. In Fig. 2b we show the distribution of e' Λ K^+ events as a function of kaon center-of-mass angles, Φ^* and $\cos\theta^*$.

5. Conclusions

The time-of-flight and tracking systems of the CLAS are working well to provide kaon identification by particle velocity measurements.

The data taken in the first year of running shows substantial, well-separated peaks at the positions of the Λ (1115), Σ (1190), Σ (1385)/Λ (1400) and at the Λ (1520).

Programs are in place to do all corrections: acceptances, efficiencies, radiative correc-

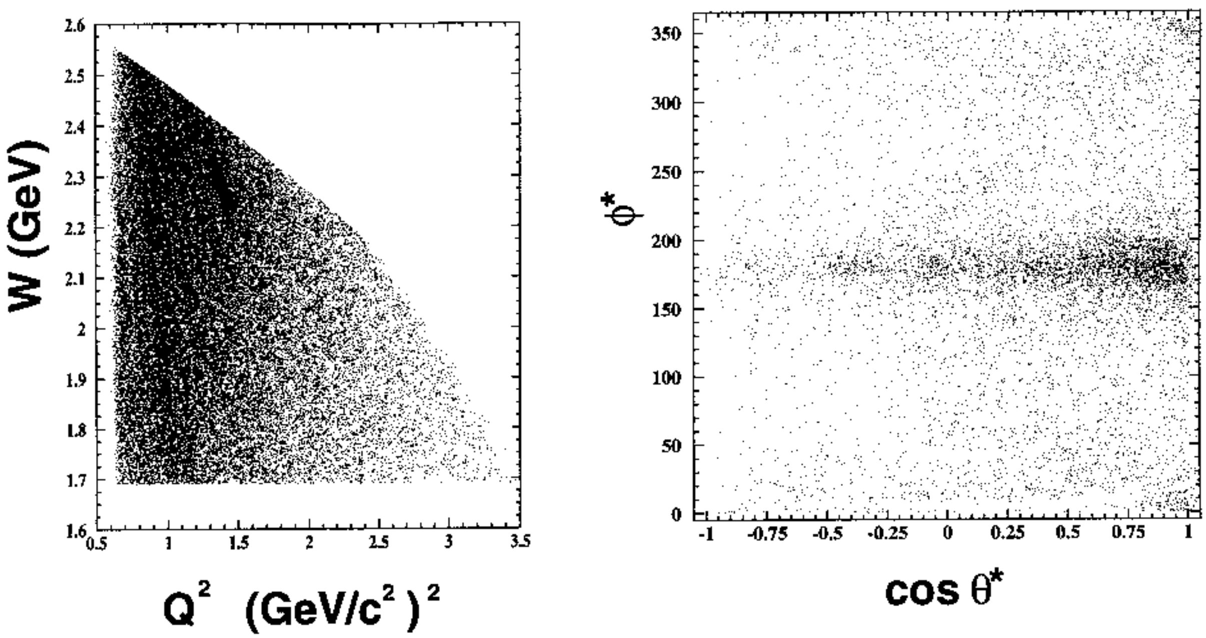

Figure 2. a) Distribution of events containing a K^+ plotted as a function of Q^2 and W. b) Event yield for Λ K^+ events, plotted as a function of K^+ center-of-mass angles, Φ^* and $\cos\theta^*$.

corrections. A factor of six more data was taken in 1999, and analysis is underway.

The large acceptance of CLAS provides nearly complete coverage in kaon center-of-mass angles. The wide coverage in Φ^* and $\cos\theta^*$ will allow determination of the four structure functions σ_T, σ_L, σ_{LT}, and σ_{TT} for K^+ hyperon final states.

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